ESO #1421

Optimal Organization of Oilseed Processing Facilities in Developing Countries: A Case Study in Sudan

By

Babiker I. Babiker[1]
Donald W. Larson[2]
E. Dean Baldwin[3]

1 Department of Rural Economy, Faculty of Agriculture, University of Khartoum, Khartoum North, Sudan

2 Department of Agricultural Economics and Rural Sociology, The Ohio State University, Columbus, Ohio 43210

3 Department of Agricultural Economics and Rural Sociology, The Ohio State University, Columbus, Ohio 43210

Abstract

Babiker, B.I., Larson, D.W., and Baldwin, E.D. 1987. "Optimal Organization of Oilseed Processing Facilities in Developing Countries: A Case Study in Sudan."

Little attention has been devoted to the study of spatial organization of marketing facilities in developing countries even though such studies would be most useful for a wide range of marketing problems. The results of such studies could be valuable to private and public decision makers in developing countries whose policies and decisions determine the number, size and location of marketing facilities. The spatial organization model developed in this paper for application to the oilseeds industry in Sudan demonstrates the relevance of this research technique for developing country studies of marketing facilities. A linear programming transshipment model is utilized to determine the optimal spatial organization of oilseeds in Sudan when the costs of oilseed assembly, processing and distribution of oil and cake to final destinations are considered simultaneously. The optimal spatial organization of oilseed processing plants was determined for six alternative solutions. Model results indicate that the optimal organization of processing plants would be obtained with fewer and larger plants resulting in lower transportation costs.

Optimal Organization of Oilseed Processing Facilities in Developing Countries: A Case Study in Sudan

Introduction

The optimal spatial organization of marketing facilities (the number, size and location of marketing facilities) in developing or developed countries can contribute significantly to lower marketing costs that benefit domestic consumers with lower prices. Lower marketing costs may improve both profits for producers, and the ability of a country to compete in export markets. Private and public decision makers in most, if not all developing countries, make policy and investment decisions on a regular basis that influence the spatial organization of marketing facilities.

Applied research results that analyze these optimal spatial organization issues could improve the information base for public and private decision makers and lead to better investment/disinvestment decisions that improve market efficiency and lower marketing costs. The spatial organization model developed in this paper for application to the oilseeds processing industry in the Sudan could easily be applied to a wide range of problems addressing the organization of marketing facilities. Common examples of the problems that can be analyzed with this approach are the number, size, and location of storage facilities for grain products (or any other storable commodity), processing plants for any food and fiber crop, rice milling, cotton ginning, sugar refining, and slaughtering plants. The results of the analysis would be of value to private decision makers in firms with multi-plant operations, to government decision makers whose policies influence plant location decisions, and to managers of government owned parastatal marketing organizations (quasi-monopolies) with multi-plant facilities. The spatial organization model can be used to evaluate the organization of existing plants or the construction of new plants.

Oilseeds production and exports in the Sudan, especially groundnuts, are undergoing critical changes in terms of production and marketing. Production of groundnuts, sesame and cottonseed are increasing as new investments and policies are introduced into the agricultural sector. In the marketing sector, policy measures to strengthen the country's comparative advantage in the world market and improve infrastructure are being undertaken. Efforts to increase processed oilseeds exports as a substitute for raw seed exports have also been an important policy objective. The increase in supply and the emphasis on exporting oil and cake rather than unprocessed seeds will affect the location, number, and size of processing plants needed to implement the planned strategy. Therefore, economic information is needed to serve as guidelines and to give more precise direction to the expected changes in marketing services.[1]

The Sudan oilseed marketing systems are rather inefficient. Sudan is geographically a large country with several important production regions for oilseeds that are distant from demand centers. Costs of transportation are high, the processing activity is concentrated and is underutilized in the capital city of Khartoum. Sudan had 87 active oilseeds processing plants in 1979 that ranged in size from less than 2,000 metric tons to over 14,000 metric tons of oilseeds processed. These plants had a total rated capacity of 1,036,000 tons of oilseeds annually but processed only 456,000 tons in the 1979/80 season.[2] If the country is to improve its comparative advantage in the world vegetable oil market, Sudan must remedy these processing and transportation inefficiencies.

The present research demonstrates the applicability of spatial analysis techniques to solving industry location problems in developing countries using an example from Sudan. It outlines the potential gains from reorganizing the oilseeds processing industry. [Babiker, 1982]

Methods of Analysis

To achieve the stated objectives, a linear programming transshipment model was used. This model minimizes costs for transshipments between origins and destinations and for storing and processing oilseeds. [Dantzig, 1963]. Parametric programming techniques that change the right hand side constraints or the objective function coefficients are used to simulate changes in supply, demand and plant operating capacity of the Sudan oilseeds industry. For this study, Sudan is divided into 12 producing centers, 7 oil and cake consumption centers and one export port, port Sudan.

The calendar year is divided into three time periods to facilitate representation of the assembly, processing and distribution activities. Period one which is the beginning of the processing season, runs from November 1 to the end of February. During the second period, March 1 to June 30, the quantities purchased are assembled and transported to the processing plants and export port; storage also occurs while processing continues. In the third period, July 1 to the end of October, transportation demands decrease as the stored oilseeds are converted into into oil and cake.

The distribution of finished products continues throughout the year. Pipeline storage for short periods before distribution to the ultimate consumers is performed by plant owners, wholesalers and to some extent by retailers. The finished products are stored at processing plants; however, storage by wholesalers and retailers is not an option in this model.

The Model

The economic value of processing any commodity is usually reflected in changing the product form which adds value and contributes to GNP through the payments for the resources used in the activity. Improvements in the organization of the oilseed processing industry as well as the infrastructure and services for the agricultural sector will have the effect of reducing marketing costs for inputs and outputs, and stimulate agricultural development.

The important economic relationships that are examined in this analysis are: 1) raw materials assembly cost (total assembly cost or TAC), 2) processing cost for changing the form of the product (total processing cost or TPC), and 3) the cost of distributing the final product to consumption centers and the export port (total distribution cost or TDC) [King and Logan, 1964]. These three costs vary with plant numbers, plant location, density of production of the raw product, volume of raw product produced and processed and the selection of transportation routes to move the processed product to consumption centers and export port.

To analyze these economic relationships within a linear programming transshipment framework, the following assumptions are used:

1. The volume of production of oilseeds is fixed for the season under consideration.
2. Each plant location will have a transportation network to support it.
3. Factor prices are assumed to be constant at all plant sites and to have no effect on location and size of plant.
4. Production and consumption are assumed to be concentrated at one point in the center of the production and consumption (demand) regions. This is to enable calculation of assembly and distribution costs for the area as a whole.
5. The oilseed supply functions and oil and cake demand functions are price inelastic and known for each region.
6. The surplus production over domestic consumption of oil and cakes is exported at the world market price where Sudan is considered a small exporter and price taker.

Assembly and Distribution Cost Estimates

Groundnuts, sesame, cottonseed and their products of oil and cakes use the same transportation facilities from auction markets and ginning factories to processing plants and from the processing plants to consumption centers.

Railroad rates and the distances between different points were obtained from the Sudan Railway Authority. Assembly and distribution costs by trucks were based on a questionnaire with a sample of 66 truckers and on interviews with 15 oilseeds merchants. Road mileages between auction markets and processing plants and between processing plants and demand centers, were calculated with a map wheel using road maps and partly obtained from the Saaty study. Using the survey data of transportation rates and distances between points, a regression of rates upon actual mileage is fitted in order to estimate transportation costs for all routes included in the model.

Processing Cost Estimates

To estimate the processing cost function, a sample of 20 processing plant owners were interviewed in Sudan. Processing costs per unit are expected to vary with plant capacity because of the assumption of economies of size in processing. Given the total costs for plants with different management levels and in different locations, a scatter diagram representing the relationship between the quantity of raw material processed and processing cost was constructed. Ordinary least squares regression was then used to estimate the coefficients of the total cost function.

Results of the Transshipment Model Analysis

Although the model was used to obtain optimal solutions for the three time periods, this paper summarizes the results of the analysis for the whole year. Table 1 provides a summary of the analysis for the six alternative solutions that were studied.[3] These solutions are as follows:

1. Optimal solution for 1979/80 with plants at 50 percent of rated capacity and limited exports of oil and cake. This was the situation in 1979/80.

2. Base model solution for 1979/80 with plants at 70 percent of rated capacity, increased oil/cake exports and reduced seed exports
3. Optimal location, number and size of plants for 1979/80 compared to the base model.
4. Domestic demand for oil and cake increases by 20 percent relative to the base model.
5. 1989/90 optimal location, number and size of plants based upon projections of raw material supply and final demand.
6. 1989/90 assumptions and closing of plants in port area because of saline water problem at those plants.

Optimal Plant Location, Number and Size for 1979/80

For this analysis, the constraint on plant capacity was relaxed to find the optimum location, size and number of plants. The total quantity of seeds produced and processed, as shown in Table 1, is the same as in the basic solution. The quantity of seeds exported and the quantities of oil and cake distributed for local consumption or exported also remain the same as in the basic solution.

This optimal solution reduces the number of processing units from 20 to 13 yet all the domestic demand and export requirements of oil and cake as specified in the basic solution are met. To determine the optimum number and size of processing plants, the total quantity of raw material optimally assigned to any location is divided by the number of processing plants in the processing unit in that particular location. Based on this procedure, the total number of processing plants has decreased from 87 to 40, a reduction of more than 50 percent as a result of the least-cost optimization procedure (Table 2). The optimum plant size ranges from 2,000 to 65,000 tons annual processing capacity compared to a range of 1,000 to 26,000 tons in the base solution for 1979/80. Because of the reorganization of the industry, total cost for performing the assembly, distribution and processing activities is L.S. 84.7 million compared to L.S. 90.5 million of the same activities in the basic solution, a reduction of L.S. 5.8 million for the year. The per unit cost, for all activities, is L.S. 134 compared to L.S. 144 for the basic solution, a seven percent improvement in efficiency.[4]

Optimal Plant Location, Number and Size for 1989/90

The projections of supply and demand of vegetable oil and cake were acquired from published data [Babiker]. Exports are treated as the residual (supply minus domestic demand) with Sudan as a price taker in the world market.

The model solution has 10 processing units comprising 29 processing plants to process the 1989/90 production compared to 87 processing plants for 1979/80 (Table 2). The average processing capacity ranges from 24,000 tons to 165,000 tons annually. Using the procedure procedure described before, the optimal solution for the 1989/90 production has fewer and larger processing plants compared to the base model. The model required the movement and processing of 1,736,280 tons of seeds with 228,510 tons of oil distributed for domestic consumption and 398,250 tons exported (Table 1). For cake 168,000 tons are distributed domestically and 945,000 tons exported. The total quantity of seeds processed represents the total expected supply for 1989/90 with no export of seeds. The total cost of transportation, processing and distribution activities is L.S. 241.5 million or L.S. 139 per ton calculated at constant 1979/80 Sudanese pounds.

Conclusions

The optimal spatial organization of marketing facilities is a significant issue in most if not all developing countries. The spatial organization model applied to oilseeds in the Sudan in the present paper is a case study example of how this technique could be applied to a wide range of marketing organization problems in developing countries.

Overall, the solution of the model has resulted in fewer and larger processing plants, lower per unit cost of transportation, and a geographical redistribution of the processing activity. A number of economic implications are indicated as a result.

For policymakers, the redistribution of the processing activity complies with the present government policy of trying to bring together the small processing plants into larger, more economic units. Since the geographical redistribution reduces the costs of transportation, this will strengthen the country's comparative advantage, and increase exports and foreign exchange earnings. Moreover, since the redistribution gives more emphasis to processing in the areas of production, it is expected to create more employment in these areas and reduce migration of the labor force to the capital city. On the other hand, processing in the areas of production will mean establishing and maintaining the necessary supporting services for the processing industry to succeed in these areas.

Table 1: Summary of Analysis, Basic Solution and Simulations for Oilseeds Industry of Sudan

Item	Optimal Solution Plants at 50% of Rated Capacity For 1979/80	Basic Solution Plants at 70% of Rated Capacity for 1979/80	Optimal Plant Location And Size For 1979/80	An Increase In Domestic Consumption Of Oilseeds By 20% For 1979/80	Optimal Plant Location And Size For 1989/90	Closing of Plants at The Port Area For 1989/90
Seeds Moved and Processed (tons)	468,936	630,255	630,255	630,228	1,736,280	1,736,280
Total cost L.S. Million	65.6	90.5	84.7	83.8	241.5	243.0
Quantity Oil Distributed Locally (tons)	137,529	137,529	137,529	165,030	228,510	228,510
Oil Exported (tons)	31,761	90,000	90,000	62,490	398,250	398,250
Oil Stored (tons)	0	0	0	0	0	0
Cake Distributed Locally (tons)	108,000	108,000	108,000	129,600	168,000	168,000
Cake Exported (tons)	192,600	294,000	294,000	272,400	945,000	945,000
Cake Stored (tons)	0	2,010	2,010	1,994	0	0
Seeds Exported (tons)	407,064	245,745	245,745	245,772	0	0

Source: Babiker

Table 2: Optimal Solution for Location, Number and Size of Processing Plants 1979/80 and 1989/90, Sudan

Item	Processing Unit Code Number Locations Defined for the Model																				Total Units Selected	Total Plants Selected
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
<u>Basic Solution, 1979/80</u>																						
Number of Processing Plants in Each Unit	7	4	6	8	2	3	5	2	8	1	2	4	3	6	7	3	4	2	6	4	20	87
Average Plant Processing Capacity, 000' tons/year	24	26	13	3	6	2	2	14	3	19	2	5	20	3	3	5	10	1	4	3		
<u>Optimal Solution, 1979/80</u>																						
Number of Processing Plants in Each Unit[a]	1	0	0	0	2	3	5	2	8	1	2	0	3	0	0	3	4	2	6	0	13	40
Optimum Plant Capacity, 000' tons/year[a]	24	0	0	0	65	17	2	65	3	35	16	0	28	0	0	27	14	36	6	0		
<u>Optimal Solution, 1989/90</u>																						
Number of Processing Plants in Each Unit[a]	1	0	0	0	2	0	5	2	0	1	2	0	3	0	0	3	4	0	6	0	10	29
Optimum Plant Capacity, 000' tons/year[a]	28	0	0	0	126	0	24	165	0	118	31	0	94	0	0	43	62	0	28	0		

[a] A zero indicates that the processing unit was excluded from the optimal solution.
SOURCE: Babiker

References

Babiker, I.B. 1982. "Regional Efficiency in the Organization of Agricultural Processing Facilities: An Application to Oilseeds Industry in the Sudan." Unpublished Ph.D. dissertation, Department of Agricultural Economics and Rural Sociology, The Ohio State University, Columbus, Ohio.

Dantzig, G.B., 1963. Linear Programming and Extensions. Princeton: Princeton University Press.

King, G.A. and Logan, S.H., 1964. "Optimum Location, Number and Size of Processing Plants with Raw Product and Final Product Shipments," Journal of Farm Economics. Vol. 46, No. 1, pp. 94-108.

Saaty, T.L., 1977. "The Sudan Transport Study," Interfaces. Vol. 8, pp. 37-57.

Acknowledgements

The authors appreciate the useful comments received from two departmental reviewers on an earlier draft of the manuscript. The authors assume the responsibility for any errors.

Footnotes

1. Marketing services include the transportation, storage, handling and processing of products in the oilseed industry.

2. Rated capacity is defined as the number of tons of seeds that a properly engineered plant can process when a continuous and even flow of seeds enters the plant 24 hours a day.

3. Because of space limitations, only two of the six alternative solutions are discussed in the present paper.

4. One Sudanese pound (L.S.) equals U.S. $2.00 at the official exchange rate in September of 1979.